Development of Cloud and Precipitation Property Retrieval Algorithms and Measurement Simulators from ASR Data
Final Technical Report

ID: DE-SC0007059
Principal Investigator: Gerald G. Mace
Institution: University of Utah
Title: Development of Cloud and Precipitation Property Retrieval Algorithms and Measurement Simulators from ASR Data

SC Division: SC-23.1
Program Manager: Ashley D. Williamson 301-903-3120
Research Areas: ASR
Project Period 09/15/2011 - 09/14/2014

Abstract: What has made the ASR program unique is the amount of information that is available. The suite of recently deployed instruments significantly expands the scope of the program (Mather and Voyles, 2013). The breadth of this information allows us to pose sophisticated process-level questions. Our ASR project, now entering its third year, has been about developing algorithms that use this information in ways that fully exploit the new capacity of the ARM data streams. Using optimal estimation (OE) and Markov Chain Monte Carlo (MCMC) inversion techniques, we have developed methodologies that allow us to use multiple radar frequency Doppler spectra along with lidar and passive constraints where data streams can be added or subtracted efficiently and algorithms can be reformulated for various combinations of hydrometeors by exchanging sets of empirical coefficients. These methodologies have been applied to boundary layer clouds, mixed phase snow cloud systems, and cirrus.

The following publication abstracts were derived from this funding and were acknowledged. The information in the abstracts summarize the technical results of this project:

Posselt, D. and **G. Mace**, 2014; The influence of parameter uncertainty on snowfall retrievals using Markov Chain Monte Carlo solution methods. Journal of Applied Meteorology and Climatology, 53, 2034-2057.

Collocated active and passive remote sensing measurements collected at U.S. Department of Energy Atmospheric Radiation Measurement Program sites enable simultaneous retrieval of cloud and precipitation properties and air motion. Previous studies indicate the parameters of a bimodal cloud particle size distribution can be effectively constrained using a combination of passive microwave radiometer and radar observations; however, aspects of the particle size distribution and particle shape are typically assumed to be known. In addition, many retrievals assume the observation and retrieval error statistics have Gaussian distributions and use least squares minimization techniques to find a solution. In truth, the retrieval error characteristics are largely unknown. Markov chain Monte Carlo (MCMC) methods can be used to produce a robust estimate of the probability distribution of a retrieved quantity that is nonlinearly related to the measurements and that has non-Gaussian error statistics. In this work, an MCMC algorithm is used to explore the error characteristics of cloud property retrievals from surface-based W-band radar and low-frequency microwave radiometer observations for a case of orographic snowfall. In this particular case, it is found that a combination of passive microwave radiometer measurements with radar reflectivity and Doppler velocity is sufficient to constrain the liquid and ice particle size distributions, but only if the width parameter of the assumed gamma particle size distribution and mass–dimensional relationships are specified. If the width parameter and mass–dimensional relationships are allowed to vary realistically, a unique retrieval of the liquid and ice particle size distribution for this orographic snowfall case is rendered far more problematic.

Hammonds, K. D., **G. G. Mace**, and S. Y. Matrosov, 2014: Approximating the backscatter cross section of ice phase hydrometeor size distributions via a simple scaling of the Clausius-Mossotti factor. Journal of Applied Meteorology and Climatology, 53, 2761-2774.

One of the challenges that limit the amount of information that can be inferred from radar measurements of ice and mixed-phase precipitating clouds is the variability in ice mass within hydrometeors. The variable amount of ice mass within particles of a given size drives further variability in single-scattering properties that results in uncertainties of forward-modeled remote sensing quantities. Nonspherical ice-phase hydrometeors are often approximated as spheroids to simplify the calculation of single-scattering properties, yet offline calculations remain necessary to quantify these radiative properties as a function of size in discrete increments. In this paper, a simple scaling of the Clausius–Mossotti factor is used that allows for an approximation of the scattering and extinction cross sections for an arbitrary mass–dimensional power-law relationship of a nonspherical particle given a single T-matrix calculation. Using data collected by the University of Wyoming King Air in snow clouds over the Colorado Park Range, the uncertainty in forward modeled radar reflectivity to assumptions regarding mass–dimensional relationships is examined. This is accomplished by taking advantage of independently measured condensed mass and particle size distributions to estimate the variability of the prefactor in the mass dimensional power law. Then, calculating the partial derivative of the radar backscatter cross sections using the scaling relationships, an estimate is made of the statistical uncertainty in forward-modeled radar reflectivity. Uncertainties on the order of 4 dB are found in this term for the dataset considered.